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ENGINEERING-GEOLOGICAL CONDITIONS OF LANDSLIDE IN THE OSTRAVA-KARVINÁ COALFIELD

(INŽENÝRSKOGEOLOGICKÉ POMĚRY SESUVU V OSTRAVSKO-KARVINSKÉM REVÍRU)

Abstract

The paper deals with a slope deformation Staříč (sequence number 2) in the Frýdek Místek district in the north-east of the Czech Republic. It makes part of a wider three-year study, which comprises 6 localities of slope movements in total (sequence numbers 1 to 6) in the Ostrava-Karviná District, in case of which there is a potential precondition for changes in stability due to undermining. In the first phase, archive materials, basic data, aerial photographs of slope deformation were studied and evaluated. Subsequently, engineering-geological mapping were performed, on the basis of which all landslide manifestations, such as starting scar, cracks, layer outcrops, hydrogeological structures etc. were recorded. After this phase, resistivity tomography measurements (geophysical method of multielectrode resistivity measurement) were taken. The mentioned methodology was applied in the interest area for the first time.

Abstrakt

Předložena publikace se zabývá svahovou deformaci Staříč (pořadové číslo 2) v okrese Frýdek Místek na severovýchodě České republiky. Je to součást širší 3-leté studie která se bude týkat celkově 6 lokalit svahových pohybů (pořadové číslo 1 až 6) v Ostravsko-karvinském revíru, u kterých je potencionální předpoklad ovlivnění stability poddolováním. V první fázi byly studovány a zhodnoceny archivní materiály, podklady, letecké snímky. Následně bylo realizováno inženýrskogeologické mapování, na základě něhož byly zaznamenány všechny sesuvné projevy, jako jsou odlučná oblast, trhliny, výchozy vrstev, hydrogeologické objekty atd. Po této fázi proběhla měření rezistivitní tomografií (geofyzikální metoda multielektrodového odporového měření). Uvedena metodika je zde poprvé uplatněna.

1 INTRODUCTION

In the Staříč locality a house No. 382, including the access road and workshop, has been continuously damaged due to slope movements since 1990. Mining impact is presumed there as the locality is situated in the working district of Staříč of Paskov Mine, where the mining activities still continue. The interest locality (fig.1) is the cadastre of the municipality Staříč, the district of Frýdek Místek, in the slope above the road No. 3-4945, state map sheet in the scale 1: 25 000, No. 25 – 212 Brušperk, a map sheet from 1: 5 000 Ostrava 9-9.

Since 1990 small cracks in the coat of the house have appeared, that have probably been caused by coal mining, and in 1995 they began to open distinctly. More serious manifestation of devastation showed in 1997. The initiator of the manifestation could have very probably been rainfall in the summer of 1995, in May and August 1996 and especially in June and July of 1997, when the rainfall exceeded the long-period average in the CR and caused a number of slides in Moravia. Currently, the slope movements are still active and a study was started to monitor the potential mining influences. In the first stage, we carried out study of archives, engineering-geological survey and geo-

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physical survey by means of resistive tomography. The results are offered in this paper. An evaluation of inclinometric measuring will follow as this requires longer monitoring.

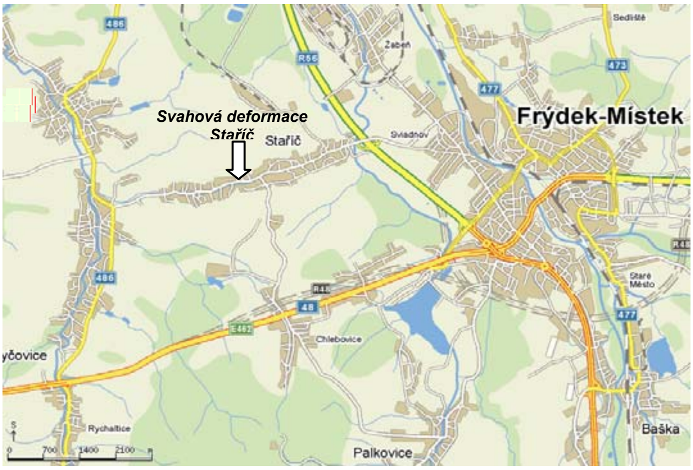

Fig. 1: Localization of the slope deformation Staříč

2 NATURAL CONDITIONS

On the basis of a new classification of higher geomorphological units of the Czech Republic, subject to the publication "Higher Geomorphological Units of the Czech Republic", the area falls in the Alpine-Himalayan system, the Carpathians subsystem, province of the Western Carpathians, subprovince of the Outer Western Carpathians, area of Western-Beskydy Foothills, the Podbeskydská pahorkatina Uplands.

The Podbeskydská pahorkatina Uplands represent a range of highlands, uplands and troughs in the direction NE-SW with a predominantly denudational relief. It roughly takes up 1508 km^2, with the mean high of 353 m and gradient 4°20′. From the point of regionally geological view the locality falls in the North-Moravian part of the flysh belt (fig.2) of the Outer Western Carpathians, the so-called Moravian-Beskydy Flysh.

The preQuarternary bedrock is formed by the rocks of the under Silesian Unit of cretaceous age, the so-called Frýdek layers, over which the Silesian Nappe was pushed, formed by upper Těšín layers. In terms of petrography it is the case of silty-clayey to clayey-siltite complex of a mostly dark-grey to black-grey colour ("Frýdek layers") and thin rhythmical flysh with the positions of rocks of teschenite association ("Těšín layers"). In the near-surface sections the preQuarternary rocks are heavily affected by intense weathering and thus transit into weathering residues of various thicknesses.

The Quarternary overlay is of a deluvial origin, it does not reach high thicknesses and it is built by eluviums of mainly Těšín layers redeposited on shorter distances.

The interest locality is directly drained by the Staříčský Stream which belongs to the Ondřejnice River catchment and the main course of Class I., No. 2-01-01 of the Odra catchment. The whole area can be characterized as low aqueous with low water retaining capacity and highly variable flow off.

The ground water of the deeper circulation is bound to the zones of fracture and fissure systems of the preQuarternary bedrock. In the consolidated Silesian Unit complex the aquifers are represented by Těšín limestone, thicker positions of sandstone of the Těšín-Hradiště Formation and igneous rock bodies of the teschenite association.

The occurrence of a shallow groundwater body is dependent on the grain-size distribution of the eluviums and the sculpturing of the surface of the Frýdek layers, representing a footwall isolator.

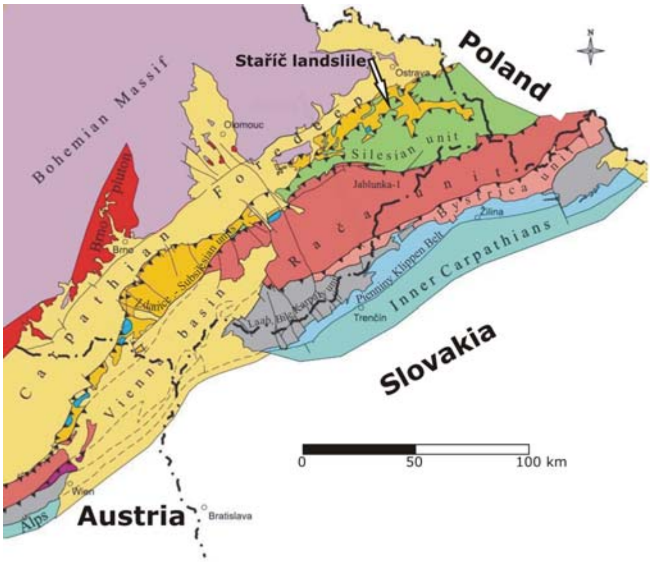

Fig. 2: Situation of Staříč landslide in Schematic geological map

3 SURVEY OF THE SLOPE DEFORMATION

Within ***the study of archives*** drilling of exploratory wells, implementation of dynamic sounding, laboratory analyses of soils and geodetic survey of exploration wells were identified.

Drilling was dry core drilling, with 100 % recovery of well core, namely in the number of 3 core exploratory wells and 1 dug hole in a house cellar. After a macroscopic description of the well core, soil sampling and survey of the ground water level, the wells were backfilled.

Dynamic sounding was carried out in order to supply information on the geological structure of the area in places which were inaccessible for the drilling rig. The principle of dynamic sounding was grounded in the monitoring of the number of 50-kilogram hammer knocks falling from the height of 0.5 m, needed to drive a drill set with a standardized bit with 43.7 mm diameter and a point angle of 90° down the soil 0.1 metre thick. On such basis it is then possible to interpret especially the grain size distribution of the soils and their consistency.

For the *laboratory analysis*, 4 undisturbed and 2 semi-disturbed samples of soils were taken. In case of the undisturbed samples, effective shear parameters and deformation characteristics (E_{oed}) and similarly to the semi-disturbed samples, basic index properties were identified.

In the interest locality it is possible to interpret the following geological section on the basis of a ***previous archive survey works*** and ***engineering-geological mapping*** (Figure 3).

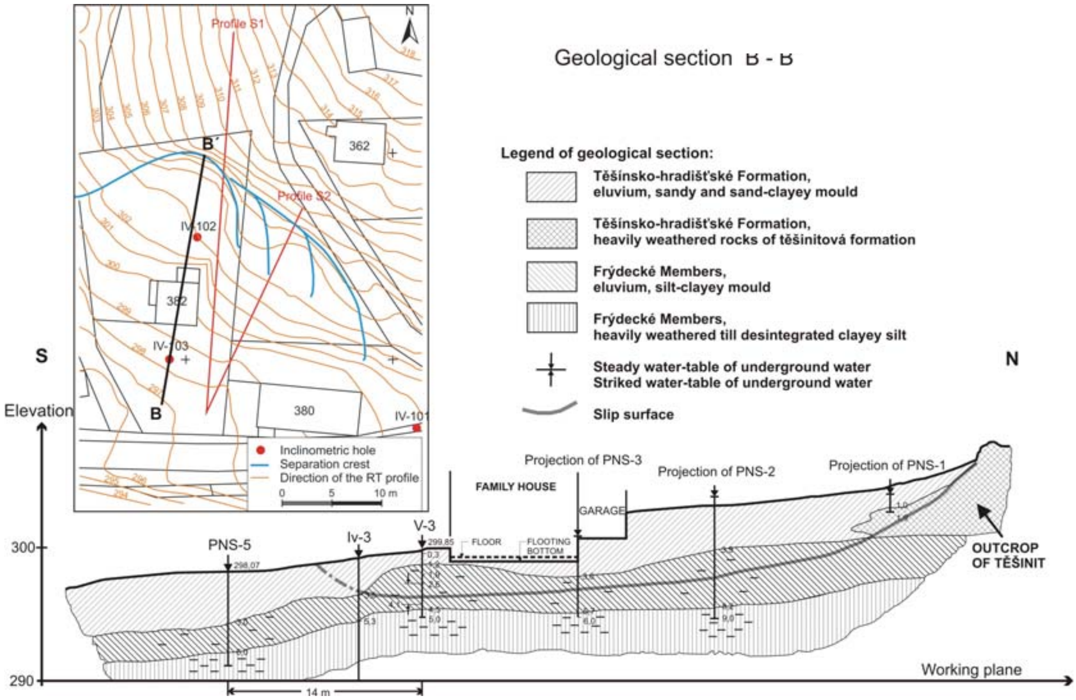

Fig. 3: Geological section and map of the interest area along with the sections placement

The following engineering-geological types of soils were defined within the geological structure of the slope deformation.

Embankments. It is the case of brown humic soil with root systems. Next, there silty-sandy loam with the shreds of bricks and stones, of soft to firm consistency and sandy loam with fine gravel, dry and low cohesive. According to ČSN 73 1001 Standard (Foundation soil under areal foundations) all the above stated soils fall in the class Y.

Slope loam (redeposited eluvia). The diluvium is represented by silty-sandy to clayey-sandy loam, which consists of rough clastics sized from 3 to 5 cm. According to ČSN 73 1001 Standard it is class F1 (MG).

Loamy-stony debris. It is loamy-stony debris of a gravel character, which comprises approximately 70% of sharp-angular shreds of 7 cm. The shreds are formed by teschenite, sandstone and claystone. According to ČSN 73 1001 Standard the layer falls in class G4 (GM).

Igneous rocks of the teschenite formation of the Těšín layers and their eluvia protrude only in the top part of the interest area and they are heavily weathered to rotten in the near surface sections. It is completely rotten teschenite of grey-green colour of a sandy loam to sandy gravel character. According to ČSN 73 1001 Standard it falls in class R6 (F4) with transition to G3.

Rotten to weathered silty claystone of the Frýdek layers and their eluvia are represented by silty light-grey claystone, which are rotten in the surface section rotten into silty-clayey loam, of firm to stiff consistency. Deeper down the quality gets better and the rocks can be characterized as heavily weathered with a well-preserved original texture, with characteristic fragmental disintegration in places. According to ČSN 73 1001 Standard it falls in class R6 (F6-CI, CL) – R4.

Table 1: Summary of geotechnical parameters

Chronological order of archive work	Rocks, soil	Apparent angle of internal friction φ_u (°)	Total cohesion c_u (kPa)	Bulk density g_n (kN/m^3)	Effective angle of internal friction φ_{ef} (°)	Effective cohesion c_{ef} (kPa)	Modulus of deformation E_{def} (MPa)	Poisson's ratio n (1)	Workability of rocks ČSN 73 3050
1st stage of archive work	Redeposited eluvia and eluvia of Těšín Members			19,5	25,5	9	4,2	0,35	3
	Eluvia and heavily weathered siltites of Frýdek Members			20,6	28,3	9	3	0,40	4
2nd stage of archive work	Silty-sandy to clayey-sandy slope loam	0	70	19,0	26,0	8	10	0,35	2-3
	Loamy-stony debris			19,0	30,0	3	15- 60	0,30	3
	Rotten rocks of teschenite formation of Těšín Members			22,1	23,0	9	4-15	0,25	2-4
	Rotten to weathered silty claystone of Frýdek Members	0	50	20,6	14,0	9	3	0,40	3-4

In the subsoil of the house, complicated foundation conditions were identified due to changes in the quality and thickness of the foundation soil.

Eluvia or deluviums of the Těšín Members (Slezský nappe) significantly differ in the hydrogeological properties from the landwaste of the Frýdek Members (Podslezský nappe). The Těšín Members can be labelled as aquiferious, with water bearing of an interstitial type, while the Frýdek Members can be labelled as insulating, with interstitial permeability. The field work did not prove the saturation of the Těšín Members, but it can occur in dependence on the climatic action. This potential saturation can considerably affect the properties of loamy eluvia and deluviums lowering their consistency. Along with repeated exsiccation of the foundation soil, this phenomenon can show negatively on the failure in the house statics.

The surface of the pre-Quarternary bedrock forms an elevation under the south-east corner of the house which can cause retention of ground water and its lifting effect (bulging of floors in the cellars).

On the basis of engineering-geological mapping all sliding manifestations, such as starting scar, steep non-overgrown slopes of the scar, cracks, deformation of the ground surface, layer outcrops, hydrogeological structures, etc. were recorded.

The tear edge of the slide is pronounced, it reaches as high as 7 m (Figure 4) and spreads in the direction NW-SE.

Fig. 4: Tear edge of the slide

As for the circumstantial evidence of the slope deformation and its active manifestation, we identified damage to the construction of the house (Figure 5), to the workshop (Figure 6), bending of trees in its vicinity (Figure 7), sliding and displacement of the top soil near the workshop (Figure 8), bent fence in the top part of the slope deformation (Figure 9), and terrain deformation with the manifestation of floor bulging in the workshop up to 15 cm (Figure 10).

Fig. 5: Damage to the construction of the house

Fig. 6: Damage to the construction of the workshop

Fig. 7: Bending of trees

Fig. 8: Sliding and displacement of the top soil near the workshop

Fig. 9: Bent fence in the top part of the slope deformation (left) Figure 10 Terrain deformation with the manifestation of floor bulging in the workshop up to 15 cm (right)

In the interest locality ***resistive tomography*** was used to measure two sections with pace survey 1 m. The first section S1, 95-metre long (96 electrodes) ran N–S with the azimuth 5° (See Figure 3 – map of the interest area along with the sections placement). The section began in the bottom part of the land belonging to house No. 382, went through an outcrop of teschenites and ended on the field of the neighbouring house No. 362. The second, shorter section S2 was 55 m long (56 electrodes). It originated from the identical source point as section 1 and with the azimuth 30° it intersected the plots belonging to houses No. 382, 380 and 362.

During processing the resistivity data from section S1 of Stařîč slope deformation, due to high resistivity in the bottom part of the section, it was necessary to choose a place of usual inversive MNČ **combined Marquardt and Occam inversion.** This method is suitable for low sensitive data if some values are extremely low.

The interpretation of the slip surfaces of *S1 section* (Figure 11) was mainly conditioned by morphology, by means of top tear edge manifestation, and next by inclinometric measuring in the bores Iv-102 and Iv-103 (bore placement – Figure 3). According to the inclinometric measuring in the bore Iv-102 an occurrence of a slip surface was proved in the approximate depth of 6-7m under the collar of well and the slip surface depth identified in the bore Iv-103 was about 3 m p. t. (under the ground). Inclinometric measurements register both movements caused by undermining in the direction of the subsidence trough as well as movements related to a slide.

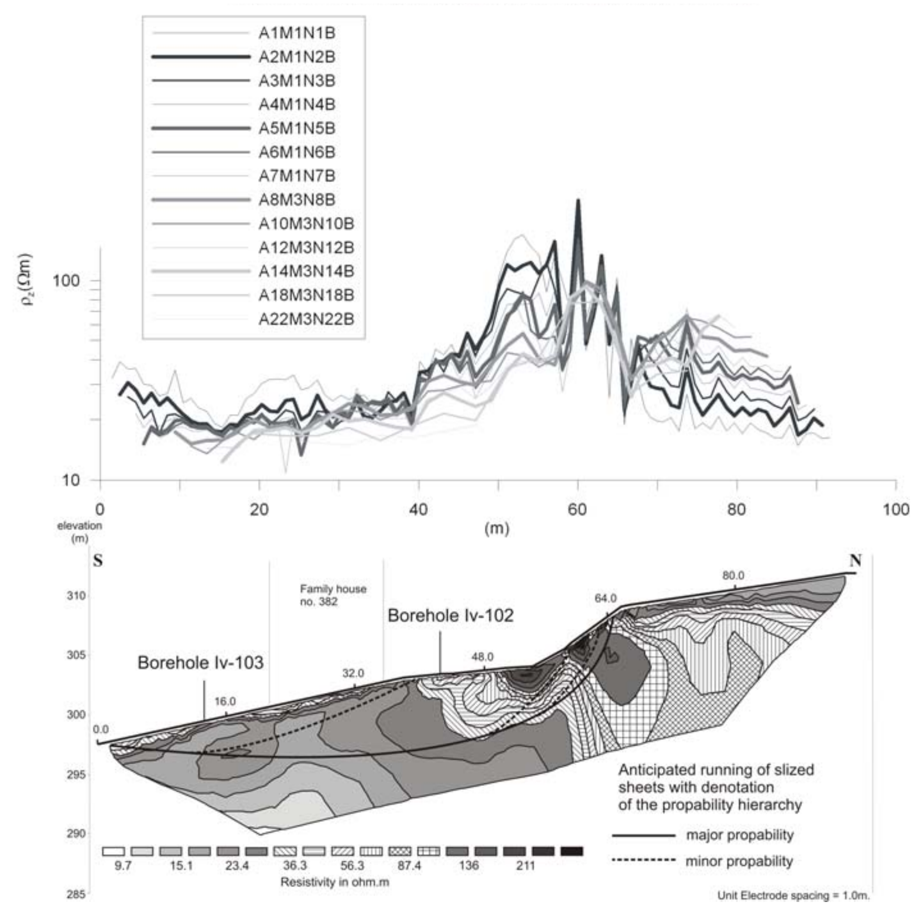

Fig. 11: Resistive model of S1 section

Resistively, the outcrop of teschenites is demonstrated by a considerable rise in resistance, 150 Ωm and more, and the course of the slip surface is situated between the maximum resistance values on the stationing 50 - 65 m and next, it runs in an inclinometrically identified depth in the bore Iv-102. Cracks were situated according to local resistive minimums both in the model as well as in the section curves.

As for lithology, the tear edge begins at the outcrop of teschenites on the stationing 65m and transits to silty claystone (it is identified in the place of bore Iv-102 2.5 m under its roof).

With the bore IV-103 in the slip surface depth there is a boundary between clayey-sandy loam and loamy-stony debris in the bedrock.

The determination of the course of the slip surface with *S2 section* (Figure 12) was only grounded in the areal continuity of the course of the slip surface as in the vicinity of the measured section there is no inclinometric bore. Similarly to the S1 section, this slip surface is affected by morphology and its course is situated between the local maximums of impedance. The maximum depth of the estimated slip surface 6 m p.t. is found on the stationing 37m.

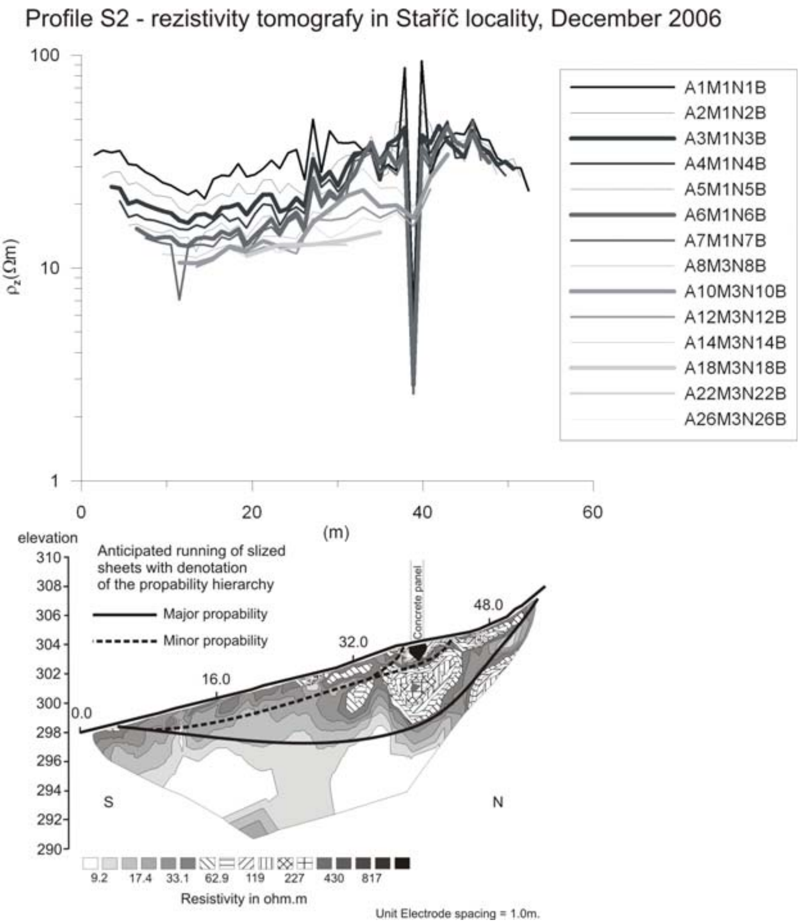

Fig. 12: Resistive model of S2 section

4 CONCLUSION

The current state of the slide in Staříč can be rated as active. In terms of potential risks, it is necessary to add all the underground services on the neighbouring lots and the adjoining roads to the damaged house.

The slope deformation is found in the working district of Staříč of Paskov Mine and it will be under the influence of mining a number of coalfaces. The impact of mining is characterized by values that classify the interest area between 1997 and 2007 as construction site class 4, according to ČSN 73 0039 Standard – Design of building on undermined areas.

However, it must be pointed out that undermining could have affected the slide in a negative way in connection with other effects (rainfall, changes in the static ground water level) and could also have affected the original geotechnical parameters of the rocks and soils. Possible acceleration of sliding or complete down-slipping of the slope is potentially possible at an anomalous increase in rainfall.

Previous field work did not prove significant saturation of the solid mass, but it can be assumed that the occurrence of saturation on the boundary of lithologically different units (impermeable siltite versus more permeable rock landwaste of the teschenite association) is, apart from potentially expected mining influence, the driving mechanism of the sliding movements in the locality.

Inclinometric measuring positively proved the existence of a slipping plane, while its existence is bound to the boundary of lithologically different units of Slezský nappe (teschenite Members) and Podslezský nappe (Frýdek Members).

On the basis of the study results, the best recommendation in order to improve the stability situation would be building a draining system in connection with subhorizontal drainage wells, which would be able to drain anomalous hydrogeological states related to potential overlimit rainfall. In order to obtain the best effect, the depth of the draining system should go along the eluvium surface of the Frýdek Members. Next, construction of static measures by means of an anchored pile wall should be built in the level of the existing supporting wall behind the house. In addition, we can suggest demolishing of the inconveniently placed garage and possible placement of heavy gabions as a stabilizing fill.

In order to evaluate the impact of the potential sliding activities in connection with the impact of undermining, a monitoring system of inclinometric wells was initiated, which will help to review this influence in the future.

5 ACKNOWLEDGEMENT

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